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Technical Report

PROTECTION OF MOORING BUOYS -
PART I. INITIATION OF FIELD TESTING

30 June 1963



U. S. NAVAL CIVIL ENGINEERING LABORATORY
Port Hueneme, California

PROTECTION OF MOORING BUOYS — PART I. INITIATION OF FIELD TESTING

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by

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ABSTRACT

This is the first of a series of reports on protection of mooring buoys. Thirteen different protective coating systems were applied to fifteen buoys at the U. S. Naval Station, San Diego. A cathodic protection system was installed on three of the buoys, and three others served as controls. The application of each coating system is described, and a cost analysis for complete overhaul and replacement of each of the test buoys is presented. The test buoys are currently serving the fleet in San Diego Bay and will be periodically inspected and evaluated for protection afforded by coatings and cathodic protection installations.

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INTRODUCTION

The Bureau of Yards and Docks is responsible for the maintenance of mooring buoys throughout the Naval Shore Establishment. The buoys must be seaworthy, capable of withstanding large forces imposed by mooring lines, and readily visible at night and in inclement weather.

The task of investigating better methods for the protection of mooring buoys was initiated by both the Design and Specification Branches of the Bureau of Yards and Docks when it was learned that field activities were experiencing unsatisfactory results with the present BuDocks-recommended coating systems for mooring buoys, chains, and fittings. All presently used protective coatings for mooring buoys discolor very quickly, and they have a maximum service life of 1 year in many locations. The U. S. Naval Civil Engineering Laboratory was asked to find or develop a suitable method for protecting mooring buoys against corrosion. This assignment was to include investigation of both improved coating systems and cathodic protection of the underwater portion of buoys and the attached mooring chains.

BACKGROUND INFORMATION

NCEL corrosion scientists contacted Public Works personnel in the First, Eleventh, Twelfth, Thirteenth, and Fourteenth Naval Districts, Coast Guard personnel in the Twelfth and Thirteenth Coast Guard Districts, and the Commandant, U. S. Coast Guard, Washington, D. C., in order to secure background information on the maintenance of mooring buoys. Much of the information to be presented in this section of this report was obtained from these sources.

The maintenance of mooring buoys presents a unique problem. No other type of buoy receives such severe treatment as banging, scraping, and overriding by naval vessels and abrasion by mooring lines. Smaller buoys of the riser-chain type are often tilted by the mooring lines from vessels (Figure 1) so that portions of the buoy normally submerged are exposed to the atmosphere and portions normally exposed to the atmosphere are submerged. This presents a special problem when an antifouling coat is used below the water line and a white topcoat is used above the water line.

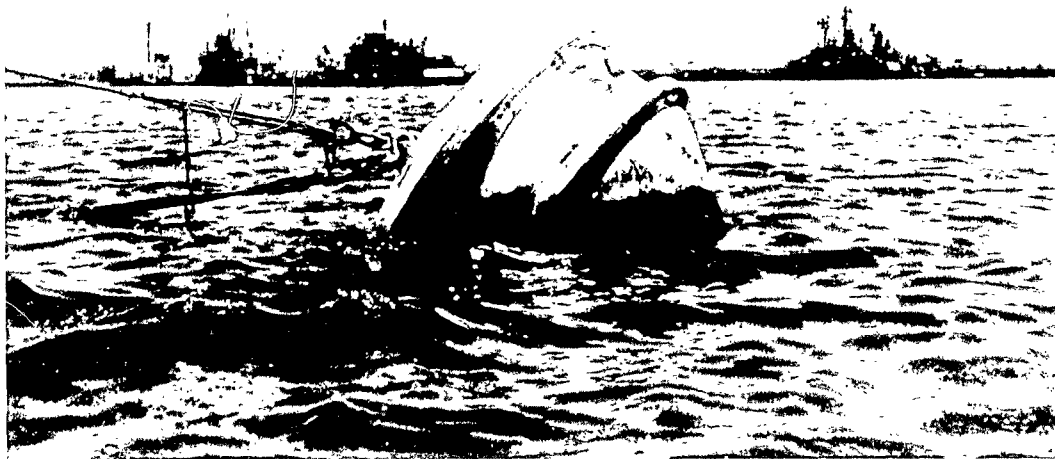


Figure 1. Mark I peg-top riser-chain buoy tilted by mooring lines.

The extent of deterioration of a protective coating system may vary widely from location to location depending upon local environment and type and amount of service rendered. When buoys are maintained according to BuDocks Instruction 11153.4A of 15 May 1963, "Inspection and Maintenance of Standard Fleet Moorings," some coatings hold up reasonably well in mild environments or where intermittent use is made of buoys. Others fail rapidly under more severe environmental and service conditions.

Environmental factors contributing to coating deterioration include temperature, humidity, type and amount of precipitation, pollution of water, type and amount of fouling, and the presence of marine birds. Deterioration of coatings and corrosion of steel proceed rapidly when the temperature is high and moisture and oxygen are abundant. Thus, the splash zone on buoys is usually the most badly damaged. Pollution of water with sewage or industrial waste may change the concentration of dissolved oxygen, the amount of fouling, or the chemical nature of the water. Large deposits of guano may accumulate on top of buoys when sea gulls or pelicans are present in the area. These deposits not only discolor coatings and corrode steel, but present a slippery footing for seamen who must climb atop buoys to attach mooring lines.

In addition to environment and type of service, a number of other factors contribute to deterioration of protective coatings. These factors include deficiencies in the design of buoys, improper application of coatings, and careless handling of coated buoys, and may to a great extent be minimized by Public Works personnel. Many buoys are equipped with side-hanging chains which apparently were intended for mooring small boats. These rapidly abrade the coating on the sides of the buoys (Figure 2) and should be removed unless specifically required. Many buoys were constructed during World War II, and little attention was given to elimination of crevices, sharp edges, and corners where concentration cells can form and accelerate corrosion. Nonfunctional modifications can be removed from buoys, sharp edges can be rounded, and crevices can be filled where flanges have been tack-welded. Staining of the sides of buoys can be minimized by using coated steel bolts to secure the wooden bumpers.

Special training can be given to Public Works personnel engaged in the maintenance of mooring buoys. All buoys requiring recoating should be sandblasted to white metal according to the best established practices. The prime coat should be applied as soon as possible on the same day that the buoys are blasted. No coating should be done when the temperature is less than 40 F or the relative humidity greater than 85 percent. Figure 3 shows the stripping from a navigational buoy of a vinyl coating that had been applied while the buoy surface was moist. The coatings on buoys are frequently damaged (Figure 4) by careless handling before being placed in service. Pads (Figure 5) should be used to protect painted surfaces from abrasion, and damaged coatings should be patched as completely as possible.

A variety of protective coating systems were used on buoys by the BuDocks PW activities, the Coast Guard personnel, and the private companies contacted. The BuDocks-recommended coating system consists of one coat of pretreatment primer MIL-P-15328B (Formula 117), two coats of phenolic primer MIL-P-12742A, and one coat of phenolic enamel (white) MIL-E-12507A above water, with one coat of antifouling MIL-P-19449 (Formula 146/50) replacing the MIL-E-12507A for underwater portions of the buoy in locations where fouling was considered to be a problem.

All Coast Guard activities contacted used a vinyl system very similar to the standard Navy vinyl system. It consists of pretreatment primer (Formula 117), vinyl red lead primer (similar to Formula 119) and vinyl-alkyd topcoat (similar to Formula 122-82) above water, with vinyl antifouling coating (Formula 121) replacing the vinyl-alkyd topcoat for underwater portions of the buoy.

Two of the private companies contacted stated that an inorganic zinc silicate coating system had been giving good service on buoys for a number of years.

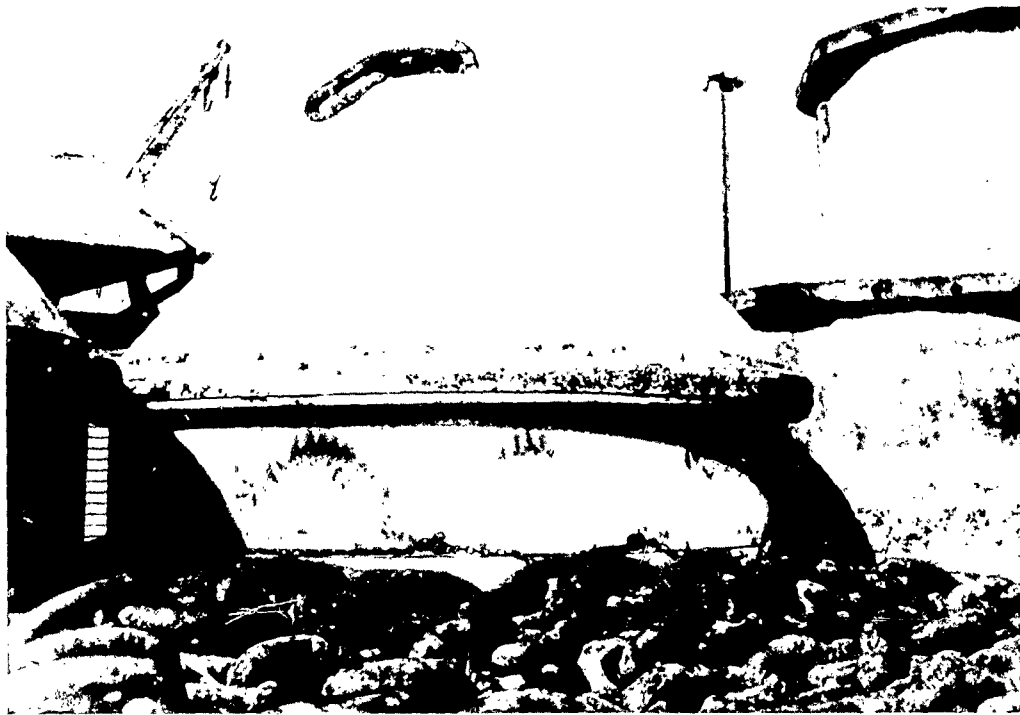


Figure 2. Buoy with coating on sides abraded by side-hanging chains.



Figure 3. Improperly applied vinyl coating being stripped from buoy.



Figure 4. Buoy with topcoat damaged during handling.

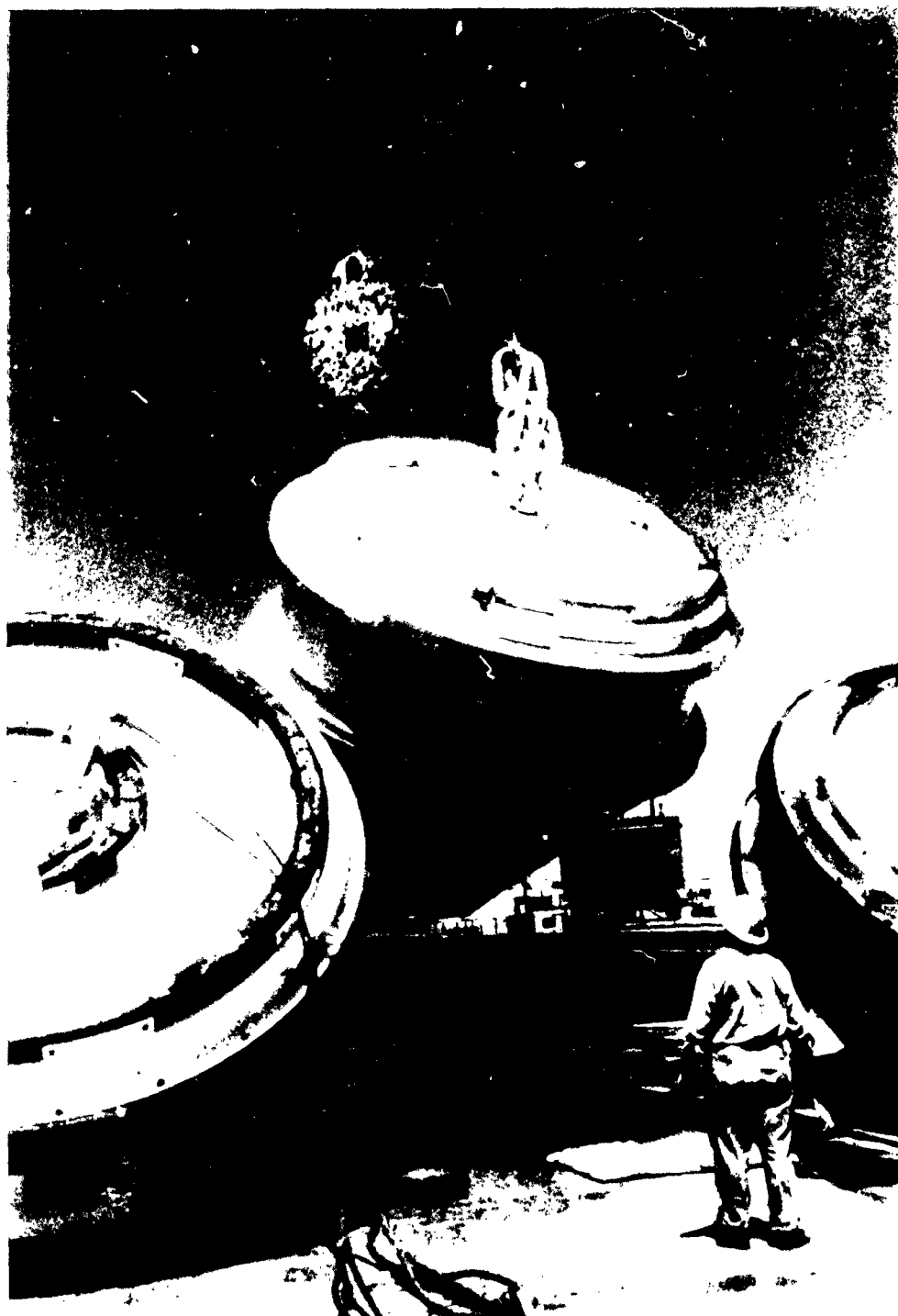


Figure 5. Buoy being lowered onto protective pads.

The protection of mooring chains presents a special problem in itself. The BuDocks-recommended coating, asphalt varnish TT-V-51c, protects the chain well in storage but is rapidly lost when the chain is placed into service. PW personnel at San Diego Naval Station have found it advantageous to coat anchor chain with cold-applied coal tar coating conforming to MIL-C-18480A. This can be accomplished conveniently and economically by dipping the chain in a tank of this coating. Riser-chain moorings show great deterioration on links in the area adjacent to the ground ring (Figure 6). Chain that remains in the mud has very little corrosion damage. Periodically reversing anchor chain end for end may distribute the wear and extend service life.

A novel method of preventing corrosion in buoys is through use of plastic buoys. It appears that this type of buoy would be better suited for navigational buoys than for mooring buoys which must take more severe treatment. Splintering of wooden fenders and denting of steel plates is a common occurrence to mooring buoys serving large vessels (Figure 7). Figures 8 and 9 show a small plastic mooring buoy that was tested by San Diego Naval Station PW personnel for BuDocks. The buoy consists of polyurethane foam covered with several layers of fiberglass and one layer of epoxy resin. A tension bar passing vertically through the center of the buoy takes all the load. After 6 months of light service the buoy had to be removed for repairs. Because of its limited buoyancy, it rode very low in the water, and the top railing and rubber bumper were broken loose by overriding moored vessels. PW personnel feel that the buoy might stand up better if changes were made in its design. NCEL has conducted an investigation¹ into plastic pontoons and found that they are rather easily damaged in side launching. Small plastic navigational buoys that were tested by the Coast Guard on rivers suffered structural damage from floating ice.

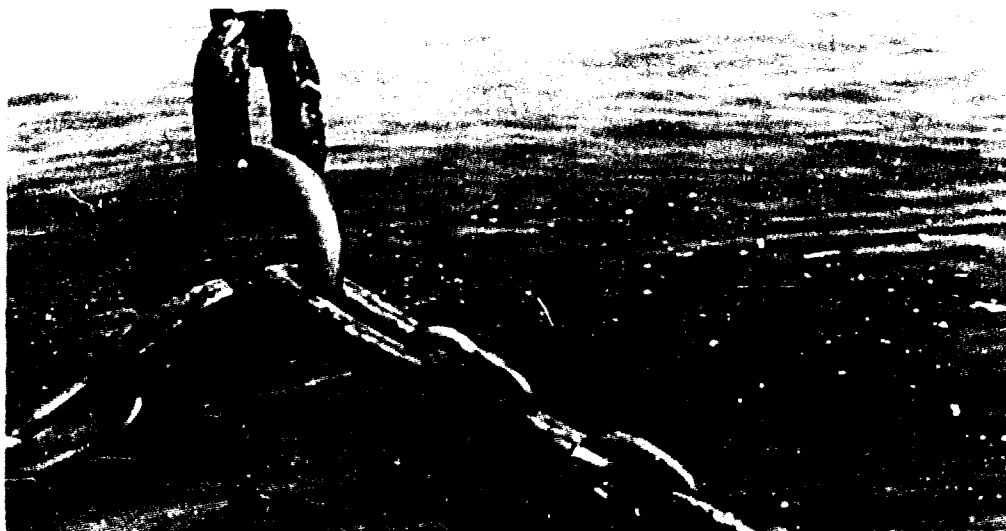


Figure 6. Heavy deterioration of chain in vicinity of ground ring.



Figure 7. Buoy damaged by overriding vessel.

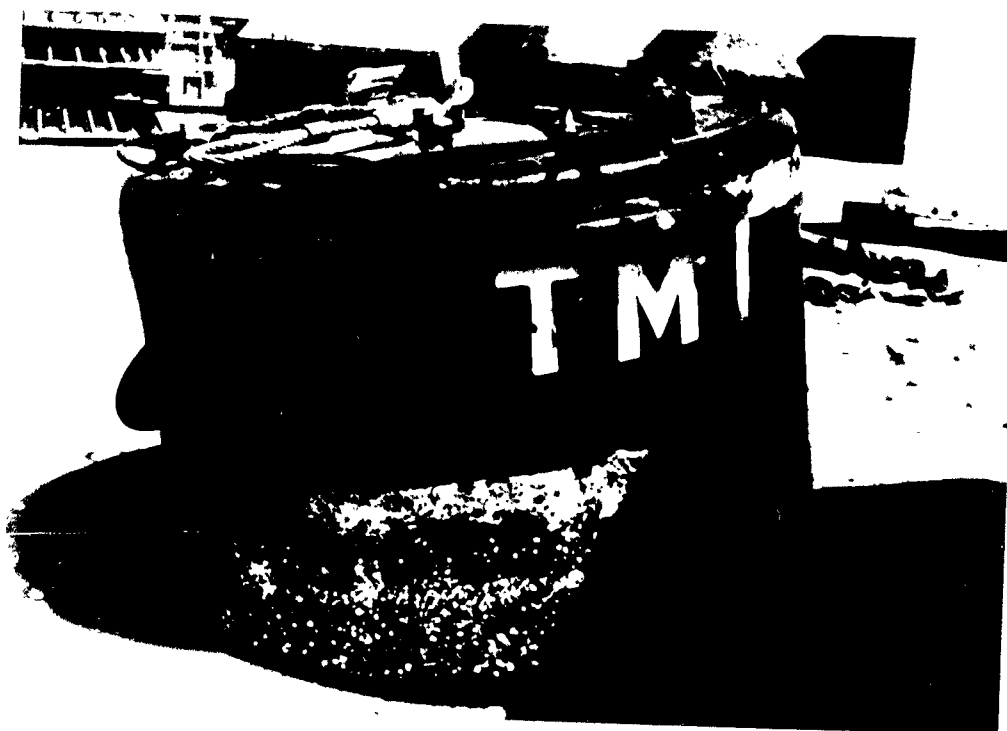


Figure 8. Damaged, plastic, test, mooring buoy.

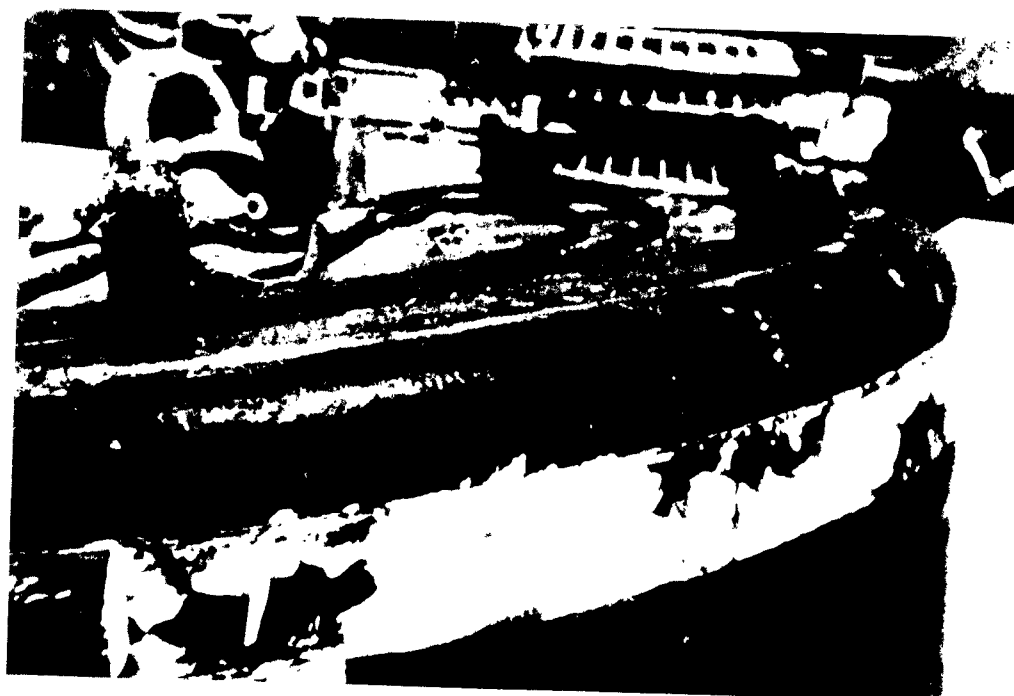


Figure 9. Broken bumper and top railing of plastic mooring buoy.

SELECTION OF TEST MATERIALS

Laboratory corrosion scientists carefully selected candidate coating systems from past field experience^{2,3,4} and from panel testing of the latest proprietary formulations. As far as possible, specification and proprietary coatings chosen were of different generic types so that a broad spectrum of coatings would be used in the program.

The cathodic protection system chosen for this phase of the program utilizes a sacrificial magnesium anode with an automatic control head, preset for a potential of -850 millivolts with respect to a standard silver-silver chloride half-cell. The supplier of this system considered it to be the best system available for the feasibility study of cathodically protecting the underwater portion of buoys. Because it was not known whether electrical continuity existed between adjacent links on a chain, a study of cathodically protecting chain was not initiated at this time.

LABORATORY ANALYSES

All specification coatings were analyzed for complete conformance to specification, and those that failed to meet specifications were returned to the supplier for replacement. Although all such coatings were specially prepared by the supplier, half of them failed to meet specifications and had to be replaced. Three of the specification coatings still failed to completely conform to specifications after they had been replaced by the supplier with another specially prepared batch. These coatings, MIL-P-12742A, MIL-E-12507A and MIL-E-1264B, are components of Systems 7C (Phenolic) and 8 (Phenolic-alkyd), to be described later. Because of the extensive time required for further replacement and analysis of these coatings and because overhaul of the moorings selected for the test program became an urgent necessity, it was decided that they should be used in the test program even though they did not completely conform to specification. The analyses of all specification coatings are given in Appendix A.

Suppliers of proprietary coatings provided information on physical properties of coatings and recommended methods of application. These coatings were analyzed at NCEL for physical properties and composition, so that subsequent changes in formulation might be detected. Analyses were based upon methods specified in Federal Test Method Standard No. 141,⁵ ASTM Standards, Part 8,⁶ and Physical and Chemical Examination of Paints, Varnishes, Lacquers and Colors.⁷ Results of Laboratory analyses of proprietary coatings appear in Appendix B.

ESTABLISHMENT OF TEST PROCEDURE

A convenient location for the field testing of protective coatings and cathodic protection for mooring buoys was found in San Diego Bay where warm waters polluted by local sewage plants provide an extremely corrosive environment.⁸ Mooring buoys in this area receive extensive use by large naval vessels, and the resultant damage from moored vessels and mooring lines greatly accelerates deterioration of protective coatings and corrosion of steel.

The Public Works Office at the United States Naval Station, San Diego, has had considerable experience in maintaining fleet moorings and offered complete cooperation with NCEL in carrying out the test program. Public Works personnel greatly contributed to establishing a sound field test program that was integrated into their regular maintenance schedule.

A site in San Diego Bay was selected where Mark I and Mark II peg-top riser-chain buoys provide bow and stern moorings for the fleet. It was felt that the slight difference in size between the Mark I and Mark II buoys (Figure 10) would not significantly affect test results.

COATING PROCEDURE

All coating systems were applied to test buoys by Public Works personnel at the U. S. Naval Station, San Diego. A corrosion scientist from NCEL was present during all coating operations to insure that all recommended procedures were followed exactly. Public Works personnel were extremely cooperative and precise in following the recommended coating procedures. All coating was done at a temperature greater than 60 F and a relative humidity less than 85 percent.

Prior to application of protective coatings, buoys were sandblasted to white metal (Figure 11), removing all dirt, rust, scale, oil or moisture which might provide a weak foundation and cause loss of adhesion. The blast cleaning not only effectively removed all scale and rust, but also roughened up the surface to provide an anchor for the coating. Special attention was paid to crevice areas which might be missed in routine blasting. Any deep pits present were filled in by welding, and the resultant slag was then removed by sandblasting.

Each coat was thoroughly mixed as recommended by specification or supplier. If an accelerator, thinner or other additive was mixed into the coating, this was done in the exact proportions and manner recommended. The induction period and pot life of coatings were carefully observed when critical time periods were specified.

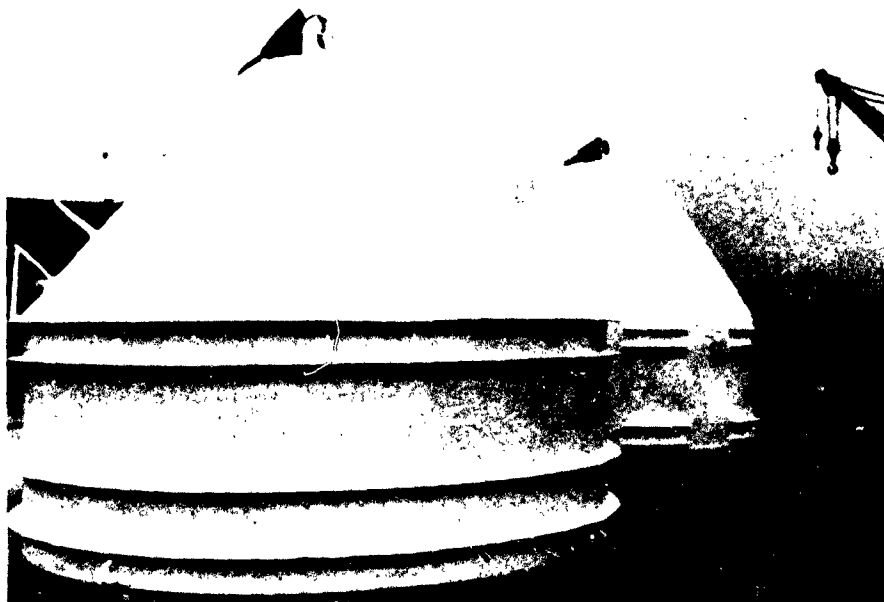


Figure 10. Mark I (right) and Mark II (left) buoys coated with Saran. Note the bars on the Mark II buoy for added protection to the anode to be installed later as part of a cathodic protection system.



Figure 11. Sandblasting buoy to white metal.

Spray equipment of the type and size recommended for use with the coating was checked for operational condition. A test patch of coating was applied to the buoy, and this was checked for proper wet film thickness and coating application. Line and gun pressures were adjusted until a proper spray pattern was received. All coatings were applied by spray (Figure 12) unless otherwise noted.

Prime coats were applied to buoys as soon as possible on the same day they had been sandblasted. Additional coats were applied after undercoats had completely dried. An extra coat was given to all corners, welds, rivets, flanges and other sharp edges or irregular surfaces.

The total dry film thickness was determined by portable magnetic gages after each coating had completely dried. Two different types of gages were used to double-check the instruments which are subject to slight variation. In all cases, the desired total dry film thickness was obtained.

A representative from the supplier of each proprietary material tested was present to give precise application instructions at the time the coating system was applied.

Method of application and dry film thickness varied from system to system as recommended by the coating supplier or specification. Each different system is described individually in the succeeding section and summarized in Table I, where individual coating thicknesses are given.

COATING SYSTEMS USED

System 1: Urethane

System 1 consisted of one coat of catalyzed urethane primer (yellow) and three catalyzed urethane topcoats (white) to give a total dry film thickness of 10 mils. The catalyst was added to both prime and topcoats and stirred with an electric stirrer for 15 minutes prior to application of coatings. Buoy flanges were brushed with primer to insure complete coverage of crevices before spraying the entire buoy with primer. No difficulties were encountered in spraying either the primer or topcoats. The topcoat yellowed slightly before the buoy was placed into service 3 weeks after coating.

Table 1. System Description and Coating Thickness

System Number	System Description	Primer		Additional Coats			Total Thickness (mils)
		Type	Coats (No.)	Thickness (mils)	Type	Coats (No.)	Thickness (mils)
1	Urethane	Urethane	1	2	Urethane	3	8
2	Epoxy	Epoxy	1	4-5	Epoxy Epoxy Antifouling	1 1 1	4 3 4
3	Epoxy-Polyester	Epoxy	1	4-5	Polyester Antifouling	2 1	5-6 4
4	Epoxy - Coal Tar Epoxy	Epoxy	1	4	Coal Tar Epoxy Epoxy Epoxy	1 1 1	4-5 4 4
5	Coal Tar Epoxy - Phenolic	Coal Tar Epoxy	1	5	Phenolic Phenolic	1 1	4-6 6-7
6 and 6C	Phenolic Mastic	Mica-Filled Phenolic	1	10-11	Phenolic Mastic	1	8-9
7C	Phenolic	Wash Primer Phenolic	1 2	0.5 4.5	Phenolic Antifouling	1 1	2-3 3
							2-9 7-8 3-8

Table 1. System Description and Coating Thickness (Cont'd)

System Number	System Description	Primer		Additional Coats			Total Thickness (mils)
		Type	Coats (No.)	Thickness (mils)	Type	Coats (No.)	Thickness (mils)
8	Phenolic-Alkyd	Wash Primer Phenolic	1	0.5	Alkyd Antifouling	1	2-3
			2	4.5		1	3
9	Vinyl	Wash Primer Vinyl	1	0.5	Vinyl-Alkyd Antifouling	3	4
			4	6.5-7.5		2	4
10	High-Body Vinyl	Vinyl	1	2	Vinyl Vinyl	2	5-6
						1	2
11	Vinyl Mastic	Vinyl-Phenolic	1	1-2	Vinyl Mastic	2	12-13
12	Inorganic Zinc Silicate - Vinyl Mastic	Inorganic Zinc Silicate Vinyl-Phenolic	1	4	Vinyl Mastic	1	5-6
			1	1-2			
13 and 13C	Saran (Formula 113/54)	--	--	--	Saran	8	8

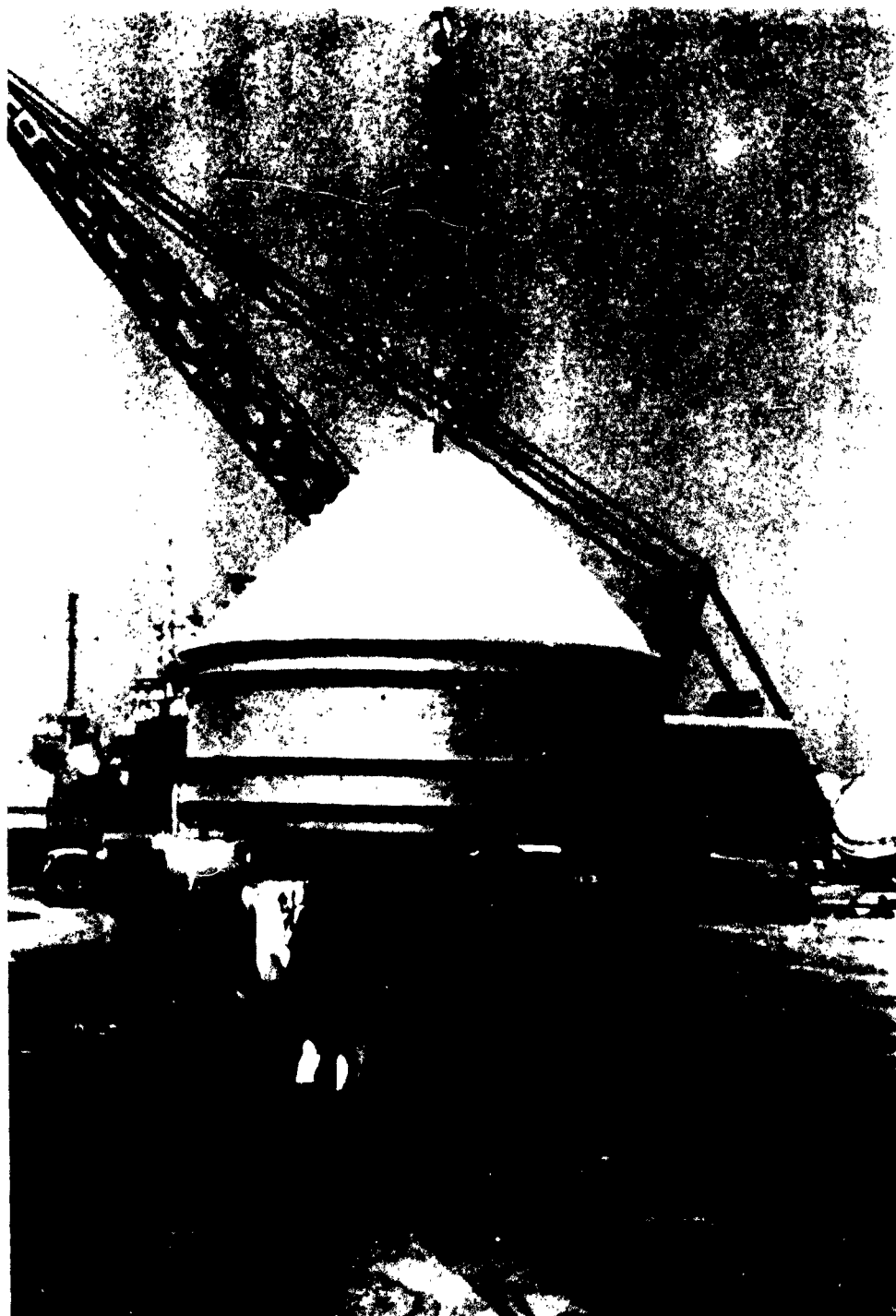


Figure 12. Spraying buoy with phenolic mastic coating; buoy over stumps for added safety.

System 2: Epoxy

System 2 consisted of one coat of catalyzed epoxy primer (yellow), one catalyzed epoxy build coat (gray), one catalyzed epoxy topcoat (white) and one coat of an antifouling (white) to the underwater portion of the buoy to give a total dry film thickness of 11 to 12 mils to the above-water portion and 15 to 16 mils to the underwater portion of the buoy. Each of the epoxy coatings had an induction period of 1-1/2 hours, and each had a pot life of 8 hours. The supplier stated that the antifouling coating contained toxic tin, arsenic, and mercury compounds. To minimize atmospheric exposure, the antifouling coating was applied 24 hours before being placed in service. No difficulty was encountered in spraying the epoxy coatings or brushing the antifouling coating.

System 3: Epoxy-Polyester

System 3 consisted of one coat of catalyzed epoxy primer (yellow) followed by two coats of catalyzed polyester (white). The supplier indicated that the pot life of the polyester was 1/2 hour, but when two 1-gallon kits were mixed together for spraying, they solidified in 20 minutes, and a complete length of hose was lost. Blisters formed overnight at a number of places between coats of polyester. These were removed with a knife and patched by spraying with polyester. The average total dry film thickness was 10 mils. The underwater portion of the buoy was painted with the same antifouling paint used in System 2; total dry film thickness was 13 to 15 mils.

System 4: Epoxy - Coal Tar Epoxy

System 4 consisted of one coat of catalyzed epoxy primer (orange), one coat of catalyzed coal tar epoxy (black), one catalyzed epoxy seal coat (gray) and one catalyzed epoxy topcoat (white); total dry film thickness was 16 to 17 mils. All coatings had an induction period of 1 hour, and all except the seal coat had a pot life of 8 hours. The reported pot life of the seal coat was 4 hours, but the coating became somewhat difficult to spray after 3 hours.

System 5: Coal Tar Epoxy - Phenolic

System 5 consisted of one coat of catalyzed coal tar epoxy (black), one catalyzed phenolic seal coat (gray) and one catalyzed phenolic topcoat (white); total dry film thickness was 15 to 18 mils. The pot life of the coal tar epoxy was 1-1/2 hours, and this coating presented no application problems. The pot life of the seal coat is reported to be 1-1/2 hours, but when three 1-gallon kits were mixed for spraying, they set up solid after 55 minutes, and a complete length of hose and a pipe fitting

were lost. Application of the topcoat presented no difficulties, but it was 3 weeks before the coating had hardened sufficiently so that the buoy could be placed in service. The topcoat yellowed slightly during this period of time.

System 6 and 6C*: Phenolic Mastic

Systems 6 and 6C consisted of one coat of catalyzed mica-filled phenolic primer (orange) and one catalyzed phenolic topcoat (white); total dry film thickness was 18 to 20 mils. Both of the heavy coatings had a pot life of 1 hour but were sprayed with no difficulty. Coating Systems 6 and 6C were identical, but 6C was applied to a buoy on which a cathodic protection system was later installed.

System 7C*: Phenolic

System 7C consisted of one coat of pretreatment primer MIL-P-15328B, two coats of phenolic primer MIL-P-12742A (yellow) and one phenolic enamel topcoat MIL-E-12507A (white); total dry film thickness was 7 to 8 mils. On the underwater portion of the buoy, one coat of antifouling, cold plastic, shipbottom black MIL-P-19449 was applied in place of MIL-E-12507A; total dry film thickness was 8 mils. No difficulty was encountered in spraying any of these coatings. A cathodic protection system was later installed on this buoy; the buoy to which System 8 was applied served as a control.

System 8: Phenolic-Alkyd

System 8 was identical to System 7C except that alkyd enamel MIL-E-1264C (white) was used as a topcoat in place of phenolic enamel MIL-E-12507A. Again, no difficulty was encountered in the spray application. The MIL-E-1264C required considerably longer application and drying time than did MIL-E-12507A.

System 9: Vinyl

System 9 consisted of one coat of pretreatment primer MIL-P-15328B, four coats of vinyl primer MIL-P-15929A (orange) and three coats of vinyl-alkyd enamel MIL-P-16738B (white); total dry film thickness was 11 to 12 mils. On the underwater portion of the buoy, two coats of vinyl antifouling MIL-P-15931A (red) were applied in place of the MIL-P-16738B; total dry film thickness was 11 to 12 mils. All coatings of this system were applied by spray gun, according to directions in Chapter 19 of BuShips Technical Manual,⁹ with no difficulties.

* The letter C indicates that the coating system was applied to a buoy on which a cathodic protection system was later installed.

System 10: High-Body Vinyl

System 10 consisted of one coat of vinyl primer (gray), two vinyl body coats (gray) and one vinyl topcoat (white); total dry film thickness was 10 mils. The primer, first body coat, and topcoat were applied with a conventional spray gun; the second body coat was applied with an airless spray gun. No difficulties were encountered with either method of application, but the airless method was at least twice as fast.

System 11: Vinyl Mastic

System 11 consisted of one coat of vinyl-phenolic primer (plum-colored) and two vinyl mastic topcoats (white); total dry film thickness was 13 to 15 mils. The primer was applied by brush and the topcoat by spray gun. No application difficulties were encountered.

System 12: Inorganic Zinc Silicate-Vinyl Mastic

System 12 consisted of one coat of a three-package inorganic zinc silicate and one coat each of the vinyl-phenolic primer and vinyl mastic topcoat used in System 11; total dry film thickness was 10 to 12 mils. The zinc silicate was sprayed by gun and double-treated with curing solution. After complete curing of the coating, the buoy was washed down with a hard stream of water and scrubbed with bristle brushes. The vinyl-phenolic primer was applied by roller. This application was twice as fast as the brush application of the same primer in System 11. The topcoat was applied by spray gun.

Systems 13 and 13C: Saran (Formula 113/54)

This consisted of eight alternate coats of vinylidene resin lacquer MIL-L-18389, Types I and II (white and orange); total dry film thickness was 8 mils. This was applied by spray gun, according to directions in Chapter 19 of BuShips Technical Manual, ⁹ with no difficulties. Coating System 13 and 13C were identical, but 13C was applied to a buoy on which a cathodic protection system was later installed.

INSTALLATION OF CATHODIC PROTECTION

The cathodic protection system was installed in a manner that provided some protection to the anode from impact by moored vessels and permitted easy removal of the anode (Figures 13-15). The larger Mark II buoys were used for the cathodic protection installations because the heavier fendering gave added protection to the

anode and because Mark II buoys are less subject to tilting by mooring lines. Two bracket plates with threaded studs were welded to the cone of the buoy, and the threads were covered with tape. U-shaped bars of 1-inch round stock were welded to the buoy to form a protective cage for the anode. After the buoy had been sand-blasted and coated, the protective tape was removed from the threads, and the remote ground cable was threaded through a series of chain links mounted under the lower fender to a point directly opposite the anode site. The automatic control head was bolted to the upper bracket plate, and the sacrificial magnesium anode was secured between the control head and a lower mounting bracket bolted to the lower bracket plate. Nylon spacers were used to isolate the anode electrically from the buoy; thus current from the anode must pass through the control head before it reaches the buoy's surface. Two of the buoys with cathodic protection had the anodes located directly under and perpendicular to the lower fender where they would receive additional protection from the fender, and the third was located closer to the peg of the cone so that it would be more fully submerged if the buoy were tilted by mooring lines.

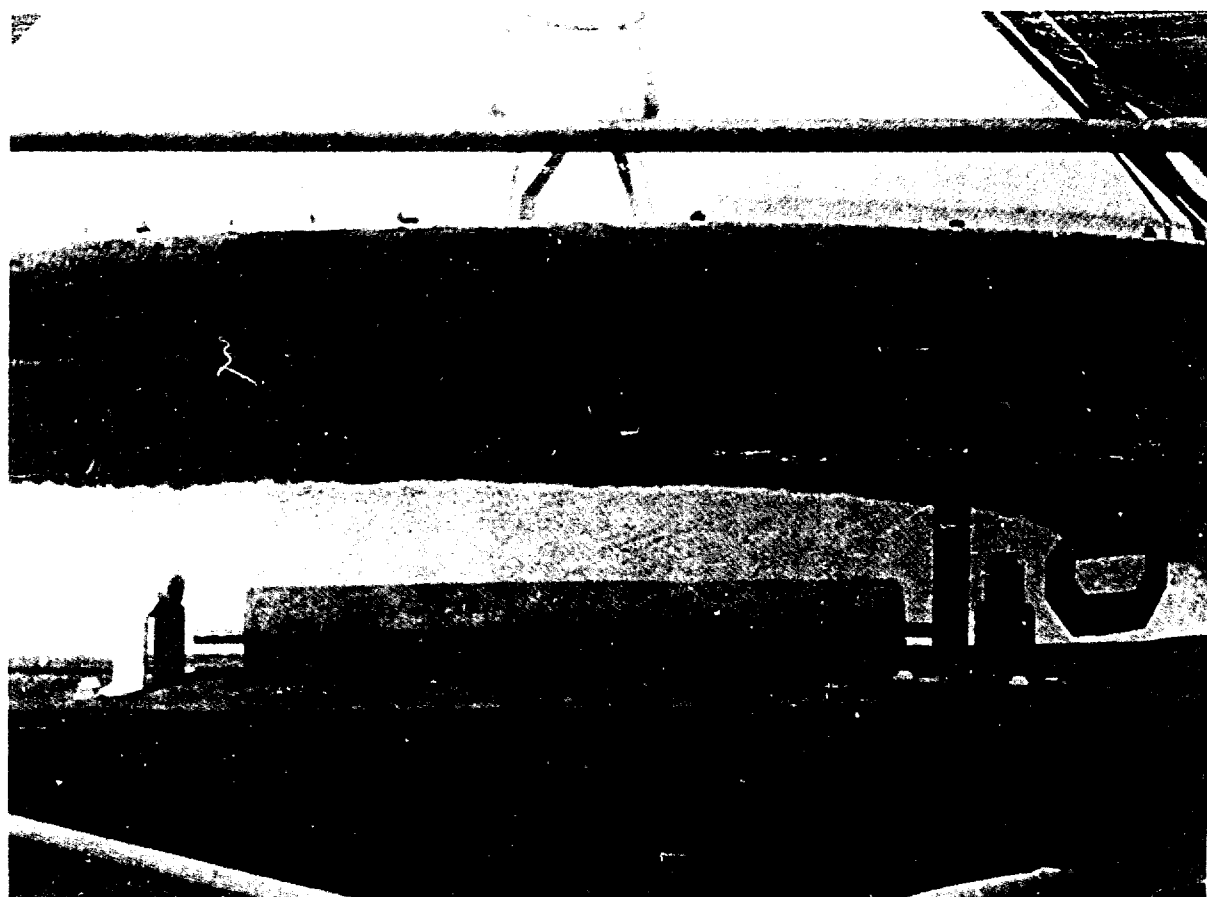


Figure 13. Cathodic protection system showing (from left to right) lower mounting bracket, sacrificial magnesium anode, and control head with attached remote ground cable.



Figure 14. Cathodic protection system installed with anode under protective steel bars and remote ground cable threaded through links.



Figure 15. Mark II buoy, with cathodic protection system, ready for laying in San Diego Bay.

The remote ground cable was then brought through the lower fender to a point on the side of the buoy above the water line. Here it was soldered to a fitting that had previously been welded to the buoy. Use of the remote ground cable distributes the cathodic protection throughout the underwater portion of the buoy.

One of the buoys with cathodic protection was part of a mooring with freshly sandblasted and coated ground tackle. The other two buoys with cathodic protection were exchanged for damaged buoys without replacing the ground tackle.

COST ANALYSIS

A cost analysis for complete overhaul and replacement of each of the test buoys is given in Table II. It is broken down into material, application, cathodic protection, and transportation costs for use by BuDocks field activities. Discussion of costs in the subsequent section of this report is largely restricted to coatings and their application.

Material costs of coatings ranged from \$0.15 to \$0.53 per square foot. Application costs ranged from \$0.55 to \$0.74 per square foot and showed no clear relationship to the material costs. Costs of coatings plus application range from \$0.70 to \$1.19 per square foot.

Material costs for specification coatings were considerably greater than usual, because they were specially prepared by suppliers in order to give them a better chance of completely conforming to specification. Thus, the material cost of Saran is listed in Table II as \$0.51 and \$0.53 per square foot per 8-mil thickness, although Alumbaugh⁴ has previously reported a price of \$0.11 per square foot per 6-mil thickness. Also, the rough, pitted surface of the buoys required greater quantities of coatings for complete coverage than would have been required for a smoother surface.

The cost of removing a Mark I buoy from service, sandblasting, and returning to service, exclusive of coating, was calculated at \$347.70. If replacement fenders were required, this would constitute an additional cost. The most expensive coating system (System 13) cost \$115.04 for the material and its application to a Mark I buoy (not including \$185.50 for sandblasting). Thus, it can be seen that the costs of coatings and their application comprised less than one-third of the total buoy overhaul costs. A considerable increase in the material and/or application costs can, therefore, be justified if they result in an appreciable increase in the service life of a buoy between required overhauls.

The cathodic protection system was sold by the supplier at cost, because it was to be included in a test program. Justification for the practice of cathodically protecting buoys would depend not only upon how well the underwater portion was thus protected but also upon whether atmospheric deterioration of coatings and corrosion of steel above the water line would necessitate premature overhaul of the buoy.

IN-SERVICE TESTING

Because it was necessary to replace buoys a few at a time and because there were lengthy delays in obtaining acceptable specification coatings, the test buoys were placed in service over a considerable time period. The initial inspection and evaluation should serve principally to screen out less-desirable coating systems, and differences in buoy exposure times should gradually become less important with increasing length of field service.

Fleet commands will, as far as is possible, distribute service over all of the test buoys.

Table II. Comparative Cost Data for Overhaul and Replacement of Buoys

System Number	Type of Buoy	Coating Materials				Application Cost <u>2</u>	Total Coating Cost		Buoy Replacement Costs <u>3</u>	Total Cost (per buoy)
		Type	Amount (gal)	Total Cost (dollars)	Cost (per sq ft) <u>1</u>		(per buoy)	(per sq ft) <u>1</u>		
1	Mark I	Primer	2.5	\$ 51.88	\$.12	\$262.18	\$449.21	\$1.00	\$162.20	\$611.41
		Topcoat	6.0	123.90	.32					
		Thinner	5.0	11.25	.03					
		Total		187.03	.43					
2	Mark I	Primer	6.0	54.00	.12	334.11	498.96	1.11	162.20	661.16
		Build coat	5.0	45.00	.10					
		Topcoat	4.0	36.00	.08					
		Antifouling Thinner	1.5	19.35	.04					
3	Mark I	Primer	6.0	10.50	.02	310.13	430.33	0.96	162.20	592.53
		Topcoat	8.0	54.00	.12					
		Antifouling Thinner	1.5	19.35	.04					
		Total	3.0	5.25	.01					
4	Mark II	Primer	6.0	54.00	.09	426.70	631.70	1.05	162.20	788.90
		C. T. Epoxy Seal coat	6.0	42.00	.07					
		Topcoat	3.5	31.50	.05					
		Thinner	5.0	60.00	.10					
5	Mark I	Primer	10.0	17.50	.03	295.75	488.60	1.09	162.20	650.80
		Seal coat	5.0	205.00	.34					
		Topcoat	4.0	49.00	.11					
		Thinner A Thinner B	4.0	65.40	.15					
5	Mark I	Primer	6.0	65.40	.15	295.75	488.60	1.09	162.20	650.80
		Seal coat	4.0	6.30	.01					
		Topcoat	3.0	6.75	.02					
		Total		192.85	.44					

Table II. Comparative Cost Data for Overhaul and Replacement of Buoys (Cont'd)

System Number	Type of Buoy	Coating Materials				Application Cost $\frac{2}{\text{buoy}}$	Total Coating Cost		Buoy Replacement Costs $\frac{3}{\text{buoy}}$	Total Cost (per buoy)
		Type	Amount (gal)	Total Cost (dollars)	Cost (per sq ft) $\frac{1}{\text{sq ft}}$		(per buoy)	(per sq ft) $\frac{1}{\text{sq ft}}$		
6	Mark I	Primer	4.0	\$108.00	\$.24					
		Topcoat	4.0	99.80	.22					
		Thinner A	0.5	1.13	.00					
		Thinner B	4.0	4.20	.01					
		Total		213.13	.47	\$261.18	\$474.31	\$1.15	\$162.20	\$636.51
6C	Mark II	Primer	5.0	135.00	.23					
		Topcoat	5.0	124.75	.20					
		Thinner A	0.5	1.13	.00					
		Thinner B	4.0	4.20	.01					
		Total		265.08	.44	339.98	605.06	1.01	387.22	992.28
7C	Mark II	Wash primer	3.5	12.25	.02					
		Primer	6.0	32.22	.05					
		Topcoat	3.5	19.15	.03					
		Antifouling	2.5	24.88	.04					
		Thinner	7.0	3.50	.01					
8	Mark II	Total		92.00	.15	330.39	422.39	0.70	387.22	809.61
		Wash primer	3.5	12.25	.02					
		Primer	6.0	32.22	.05					
		Topcoat	3.5	18.97	.03					
		Antifouling	2.5	24.88	.04					
		Thinner	7.0	3.50	.01					
		Total		91.82	.15	335.19	427.01	0.70	162.20	589.21

Table II. Comparative Cost Data for Overhaul and Replacement of Buoys (Cont'd)

System Number	Type of Buoy	Coating Materials				Application Cost <u>2/</u>	Total Coating Cost		Buoy Replacement Costs <u>3/</u>	Total Cost (per buoy)
		Type	Amount (gal)	Total Cost (dollars)	Cost (per sq ft) <u>1/</u>		(per buoy)	(per sq ft) <u>1/</u>		
9	Mark I	Wash primer	2.5	\$ 8.75	\$.02					
		Primer	15.0	85.05	.19					
		Topcoat	5.0	28.60	.06					
		Antifouling	3.0	35.61	.08					
		Thinner	5.0	5.25	.01					
10	Mark I	Total		163.26	.36	\$270.54	\$433.80	\$0.96	\$162.20	\$596.00
		Primer	5.0	34.10	.08					
		Body coat	6.5	40.50	.09					
		Topcoat	5.0	34.10	.08					
		Thinner A	1.75	4.38	.01					
11	Mark II	Thinner B	3.0	3.15	.01	278.19	394.42	0.88	162.20	556.62
		Total		116.23	.27					
		Primer	4.0	38.00	.06					
		Topcoat	13.0	92.30	.15					
		Thinner	4.5	15.30	.03					
12	Mark II	Total		145.60	.24	381.65	527.25	0.92	162.20	689.45
		Zinc Silicate	4.0	66.00	.11					
		Curing								
		Solution	10.00	50.00	.08					
		Primer	4.0	38.00	.06					
		Topcoat	6.5	46.15	.08					
		Thinner	9.0	30.60	.05					
		Total		230.75	.38	366.00	596.75	1.00	162.20	758.95

Table II. Comparative Cost Data for Overhaul and Replacement of Buoys (Cont'd)

System Number	Type of Buoy	Coating Materials			Application Cost ^{2/}	Total Coating Cost		Buoy Replacement Costs ^{3/}	Total Cost (per buoy)
		Type	Amount (gal)	Total Cost (dollars)		(per buoy)	(per sq ft) ^{1/}		
13	Mark I	White	21.0	\$113.82	\$300.54	\$532.38	\$1.18	162.20	\$694.58
		Orange	21.0	111.72					
		Thinner	6.0	6.30					
		Total		231.84					
13C	Mark II	White	29.0	157.18	397.52	715.28	1.19	387.72	1103.00
		Orange	29.0	154.28					
		Thinner	6.0	6.30					
		Total		317.76					

^{1/} Mark I buoys were considered to have 450 sq ft of surface area and Mark II buoys 600 sq ft.

^{2/} Application costs include sand for sandblasting at \$9.50 per ton and labor costs based upon the following salary schedule: sandblaster and helper — \$5.56/hr; painter — \$3.21/hr; rigger — \$3.19/hr; and operator — \$3.19/hr. Because of the nature of the sandblasting and painting procedure, the services of one rigger were required per sandblaster and helper and one rigger and one operator per painter.

^{3/} Buoy replacement costs include transporting buoy to mooring yard and back to mooring site (\$77.20 per buoy, assuming buoys are replaced four at a time), and cost of cathodic protection equipment (\$200.00) and installation (\$25.52) where applicable. Cost of new wooden fenders was not included because not all buoys required new fenders. A cost of \$85.00 was included for new bolts and the removal and replacement of fenders (required for sandblasting).

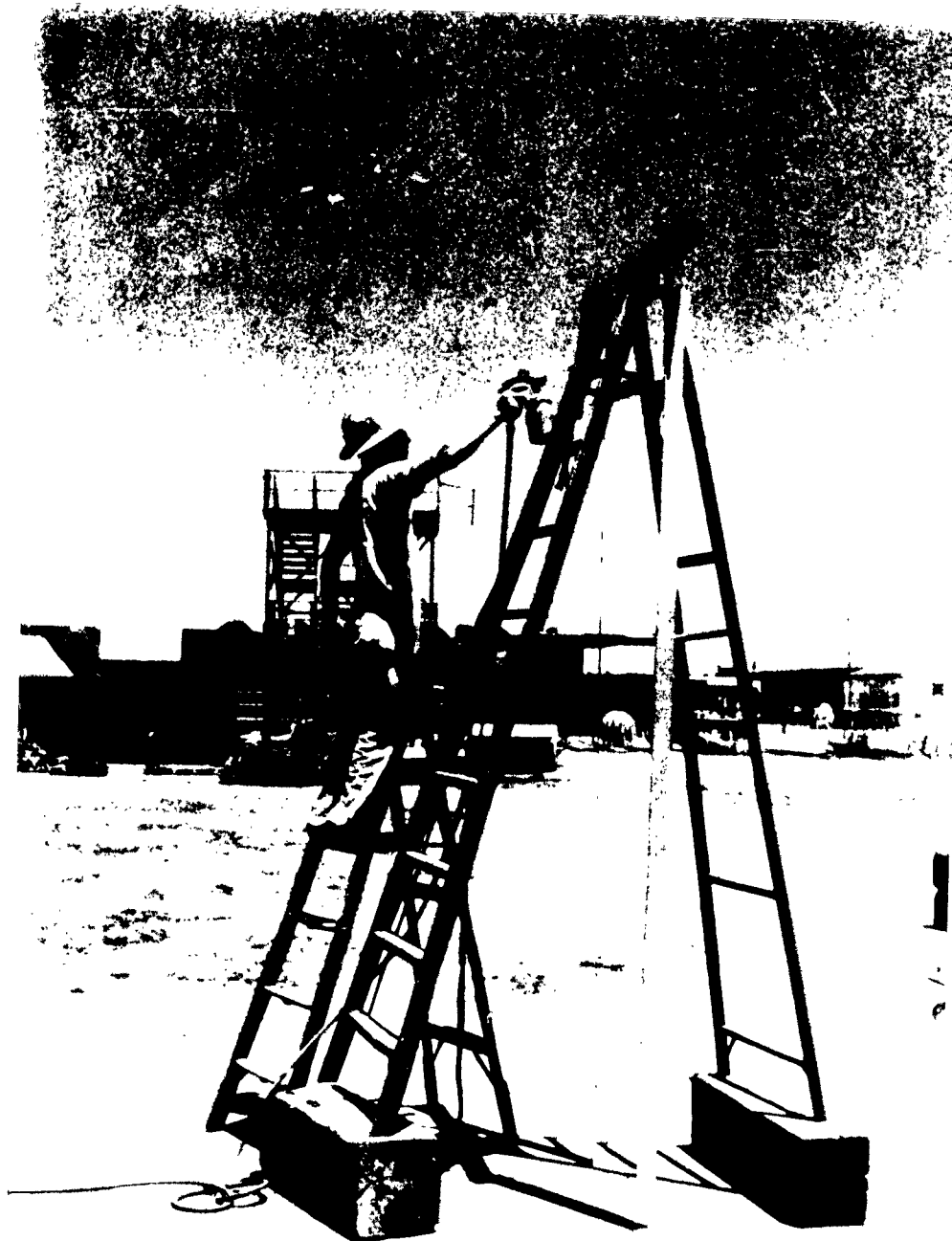


Figure 16. Coating steel test panels.

At the time of coating the test buoys, two steel test panels 10 feet long, 4 inches wide, and 1/4 inch thick were coated with each of the test coating systems with the same equipment and conditions as each of the test buoys (Figure 16). One set of 13 panels was suspended from a pier in San Diego Bay and the other from a pier in Port Hueneme Harbor. They were exposed so that a portion of each panel was continually submerged, another portion was subjected to tidal changes, and a third portion was continually exposed to the atmosphere. These panels may give information on how much protection each coating system provides in a marine environment when abrasive forces are not present.

ASSISTANCE TO FIELD ACTIVITIES

A colored motion picture, Y&D No. 6-62, "Protection of Mooring Buoys, Phase I - Initiation of Field Testing" has been prepared by NCEL. This film describes problems associated with the laying and picking up of fleet moorings, as well as the buoy test program in San Diego. It is available on loan to field activities and may be borrowed from either NCEL or BuDocks. Field activities desiring additional information on coatings for the protection of mooring buoys may contact NCEL.

FINDINGS

1. Deficiencies in design as well as improper handling of coated buoys may result in significantly accelerated deterioration of coatings and corrosion of steel.
2. Ease of application of coatings varied considerably.
3. Material costs for different coating systems ranged from \$0.15 to \$0.53 per square foot, application costs from \$0.55 to \$0.74 per square foot, and material plus application costs from \$0.70 to \$1.19 per square foot.

CONCLUSION

An increase in material and/or application costs of a new coating system may be justified by an increase of the service life of the buoy between required overhauls.

RECOMMENDATIONS

1. Side-hanging chains and other non-functional appendages should be removed from mooring buoys.
2. Pads should be used to protect the coated surfaces of buoys to prevent abrasion during handling.
3. Coated bolts should be used for securing wooden fenders to buoys.
4. Sandblasting and coating application procedures recommended by specification or suppliers should be standard practice.
5. Buoys should be coated as soon as possible on the same day after sandblasting.
6. Coatings should not be applied when the humidity is greater than 85 percent or when the temperature is below the minimum set for the particular coating.
7. Initial inspection of test buoys should occur shortly after the first buoys have been 6 months in service.

ACKNOWLEDGMENTS

The authors of this report are grateful to the several field activities that provided background information on fleet moorings. The Public Works Office of San Diego Naval Station was most cooperative in conducting the field test program. Special credit should be given to Mr. Earl J. Kiefer of the Public Works Office of San Diego Naval Station, who, with his technical knowledge and field experience in maintaining fleet moorings, contributed greatly to the establishment of a sound test program, and who, through his direction of the various Public Works shops personnel, assisted in getting properly coated buoys into service in a minimum of time.

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Appendix A

ANALYTICAL DATA ON SPECIFICATION COATINGS

ANALYSIS OF PRETREATMENT PRIMER MIL-P-15328B (Formula 117)

<u>Test Item</u>	<u>Requirements</u>	<u>Test Results</u>
Pigment, %	9.5 - 11.0	9.84
Volatile, %	79.0 - 81.5	81.1
Non-volatile vehicle, %	8.5 - 10.0	9.1
Ratio, pigment to non-volatile vehicle	9.7: 9 to 10.3: 9	9.7:9
Pigment, chromium trioxide, %	13.5 minimum	14.2
Pigment, zinc oxide, %	57.0 minimum	57.3
Water, %	conform	conforms
Color	conform	conforms
Condition in container	conform	conforms
Weight per gallon, lbs resin	7.3 - 7.7	7.4
Coarse particles, %	0.5 maximum	0.08
Grind	6 minimum	6
Odor	conform	conforms
Consistency, Krebs Units of resin	63 - 75	67
Dry hard, minutes	30 maximum	13
Mixing and application properties	conform	conforms
Compatibility	conform	conforms

<u>Test Item</u>	<u>Requirement</u>	<u>Test Results</u>
Distillation of resin component:		
Initial boiling point, C	75 - 82	77
Temperature at 80-ml point, C	85 maximum	82
Temperature at 105-ml point, C	116 minimum	116
End-point temperature, C	120 maximum	117
Volume at end point, ml	115 minimum	122
Butanol	conform	conforms
Characteristics of acid component:		
Phosphoric acid, %	15.0 - 16.5	16.1
Distillation:		
Initial boiling point, C	75 - 82	75
Temperature at 105-ml point, C	83 maximum	80
Volume at end point, ml	125 minimum	128
Maximum distilling temperature, C	102 maximum	100
Adhesion	conform	conforms
Remarks: Conforms completely		

ANALYSIS OF PHENOLIC PRIMER MIL-P-12742A

Pigment, %	69.5 - 71.5	71.0
Volatile, %	30 maximum	27.1
Non-volatile, %	70 minimum	72.9

<u>Test Item</u>	<u>Requirement</u>	<u>Test Results</u>
Water, %	0.3 maximum	trace
Viscosity, Krebs Units	80 - 100	91
Weight per gallon, lbs	11.0 minimum	11.6
Dry through, hrs	72 maximum	8
Grind	5 minimum	5
Color	conform	conforms
Gloss	15 maximum	11
Flexibility	conform	conforms
Working properties	conform	conforms
Vehicle solids, %	28.5 - 30.5	29.0
Condition in container	conform	conforms
Self-lifting properties	conform	conforms
Baking properties	conform	conforms
Dry tack-free, hrs	6 maximum	1
Water immersion	conform	conforms
Salt-spray resistance	conform	conforms
Accelerated weathering	conform	conforms
Skinning	none	none
Rosin	none	none

<u>Test Item</u>	<u>Requirements</u>	<u>Test Result</u>
Chromium as ZnCrO_4 , %	55 - 62	50.4
TiO_2 , %	11 minimum	11.3

Remarks: Chromium as ZnCrO_4 is low

**ANALYSIS OF ANTIFOULING, COLD PLASTIC, SHIP-BOTTOM, BLACK
MIL-P-19449 (Formula 146/50)**

Pigment, %	42.5 - 44.5	43.1
Volatile, %	22.5 maximum	20.3
Weight per gallon, lbs	11.9 minimum	12.1
Coarse particles, %	1.0 maximum	0.13
Grind	4 minimum	6
Consistency, Krebs Units	80 - 84	81
Set-to-touch, minutes	10 maximum	9
Dry firm, hrs	3-1/2 maximum	2-3/4

Remarks: Conforms completely

ANALYSIS OF PHENOLIC ENAMEL MIL-E-12507A

Volatile, %	40 maximum	32.6
Non-volatile, %	60 minimum	67.4
Grind	4 minimum	5
Moisture, %	1.0 maximum	0.3
Gloss	8 maximum	3

<u>Test Item</u>	<u>Requirement</u>	<u>Test Result</u>
Viscosity, seconds	75 - 100	75
Dry dust-free, minutes	30 maximum	15
Dry through, hrs	2 maximum	1
Dry hard, hrs	16 maximum	8
Weight per gallon, lbs	report	11.4
Condition in container	conform	conforms
Working properties	conform	conforms
Trichromatic coefficient X	0.297 - 0.320	0.323
Trichromatic coefficient Y	0.303 - 0.338	0.332
Self-lifting properties	conform	conforms
Baking properties	conform	conforms
Immersion resistance	conform	conforms
Storage stability	conform	conforms
Reflectance, %	80 minimum	83
Salt-spray resistance	conform	conforms
Accelerated weathering	conform	conforms
Flexibility	conform	conforms
Elongation, %	8 minimum	conforms
Dry hiding power, sq ft/gal	300	300
Phenolic resin	present	present

<u>Test Item</u>	<u>Requirement</u>	<u>Test Result</u>
Rosin	none	none
Inert material in pigment, %	50 maximum	46.5

Remarks: Trichromatic coefficient X high

ANALYSIS OF ALKYD ENAMEL MIL-E-1264C

Pigment, %	36.0 - 39.5	35.4
Volatile, %	30.5 - 34.0	29.8
Non-volatile vehicle, %	29.5 - 33.0	34.8
Water, %	0.5 maximum	0.5
Coarse particles, %	0.5 maximum	trace
Viscosity, Krebs Units	67 - 77	77
Weight per gallon, lbs	10.3 - 10.7	10.5
Set-to-touch, hrs	1.5 maximum	1
Dry hard, hrs	8	8
Compatibility	conform	conforms
Flash point, F	100 minimum	102
Grind	5 minimum	6
Color	conform	conforms
Flexibility	conform	conforms
Odor	normal	normal
Condition in container	conform	conforms

<u>Test Item</u>	<u>Requirement</u>	<u>Test Result</u>
Phthalic Anhydride, %	23.0 minimum	24.4
Rosin	none	none
Phenolic resin	none	none
TiO ₂ , %	60.5 minimum	57.5
ZnO, %	22.5 minimum	23.0

Remarks: Pigment low, volatile low, non-volatile vehicle high, TiO₂ low

ANALYSIS OF VINYL PRIMER MIL-P-15929A

Pigment, %	21.0 - 24.0	21.7
Volatile, %	59.0 - 63.0	61.2
Non-volatile vehicle, %	15.0 - 18.0	17.1
Pigment analysis:		
Red lead, (Pb ₃ O ₄), %	97 minimum	97.9
Water, %	1.0 maximum	0.3
Color	conform	conforms
Weight per gallon, lbs	9.2 - 9.8	9.8
Coarse particles, %	0.5 maximum	0.2
Grind	5 minimum	6
Odor	conform	conforms
Consistency, Krebs Units	68 - 78	68
Set-to-touch, minutes	15 maximum	6

<u>Test Item</u>	<u>Requirement</u>	<u>Test Results</u>
Dry hard, minutes	30 maximum	12
Compatibility	conform	conforms
Adhesion	conform	conforms

Remarks: Conforms completely

ANALYSIS OF VINYL ANTIFOULING MIL-P-15931A

Pigment, %	53.0 - 57.5	54.9
Volatile, %	30.0 - 33.0	31.2
Non-volatile vehicle, %	12.0 - 14.0	13.9
Pigment analysis:		
Total copper, %	85 minimum	85.1
Water, %	1.0 maximum	0.2
Weight per gallon, lbs	13.8 - 14.6	14.2
Coarse particles, %	1.0 maximum	0.19
Grind	5 minimum	5
Odor	conform	conforms
Consistency, Krebs Units	65 - 80	72
Set-to-touch, minutes	15 maximum	5
Dry hard, minutes	45 minimum	28
Compatibility	conform	conforms

<u>Test Item</u>	<u>Requirement</u>	<u>Test Result</u>
Adhesion	conform	conforms
Film characteristics	conform	conforms

Remarks: Conforms completely

ANALYSIS OF VINYL-ALKYD ENAMEL MIL-E-16738B (Formula 122-82)

Pigment, %	19.0 - 22.0	21.5
Volatile, %	53.0 - 57.0	53.0
Non-volatile vehicle, %	24.0 - 27.0	25.5
Water, %	0.5 maximum	trace
Coarse particles, %	0.5 maximum	trace
Viscosity, Krebs Units	60 - 67	61
Weight per gallon, lbs	8.6 - 9.0	9.0
Set-to-touch, minutes	15 maximum	3
Dry hard, minutes	30 maximum	20
Compatibility	conform	conforms
Grind	5 minimum	6
Color	conform	conforms
Gloss	25 - 40	34
Odor	normal	normal
Adhesion	conform	conforms
Condition in container	conform	conforms

<u>Test Item</u>	<u>Requirement</u>	<u>Test Result</u>
Phthalic Anhydride, %	14.0 - 18.0	16.6
Chlorine, %	17.0 - 20.0	18.5
Rosin	none	none
Phenolic Resin	none	none
TiO ₂ , %	92.0 minimum	92.9
Remarks: Conforms completely		

ANALYSIS OF VINYLIDENE RESIN LACQUER MIL-L-18389 TYPE I (SARAN, WHITE)

Pigment, %	6.0 - 8.5	6.6
Volatile, %	75.0 - 80.5	79.0
Non-volatile vehicle, %	13.5 - 16.5	14.4
Pigment analysis:		
Titanium dioxide, %	95 minimum	95.5
Color	conform	conforms
Weight per gallon, lbs	7.4 - 7.8	7.6
Coarse particles, %	1.0 maximum	0.03
Grind	7 minimum	7
Odor	conform	conforms
Consistency, Krebs Units	60 - 67	61
Characteristics of extracted resin:		
Chlorine, %	56.5 - 60.0	58.48
Nitrogen, %	4.7 - 5.8	4.97
Viscosity (15% in M.E.K.)	G - J	G

<u>Test Item</u>	<u>Requirement</u>	<u>Test Result</u>
Characteristics of extracted thinner:		
Specific gravity, 20/20 C	0.804 - 0.809	0.804
Initial boiling point, C	78 minimum	78
90-ml point temperature, C	80 maximum	79.5
Dry-point temperature, C	82 maximum	82

Remarks: Conforms completely

ANALYSIS OF VINYLIDENE RESIN LACQUER MIL-L-1839 TYPE II (SARAN, ORANGE)

Pigment, %	3 - 5	3.1
Volatile, %	78.0 - 83.0	82.5
Non-volatile vehicle, %	14.0 - 17.0	14.4
Pigment analysis, %:		
Chromium (as PbCrO_4)	72 minimum	73.8
Molybdenum (as PbMoO_4)	10 minimum	11.77
Color	conform	conforms
Weight per gallon, lbs	7.2 - 7.6	7.3
Coarse particles, %	1.0 maximum	0.12
Odor	conform	conforms
Grind	7 minimum	7
Consistency, Krebs Units	60 - 67	60

<u>Test Item</u>	<u>Requirement</u>	<u>Test Result</u>
Characteristics of extracted resin, %:		
Chlorine	56.5 - 60.0	59.54
Nitrogen	4.7 - 5.8	5.02
Viscosity (15% in M.E.K.)	G - J	J
Characteristics of extracted thinner:		
Specific gravity, 20/20 C	0.804 - 0.809	0.804
Initial boiling point, C	78 minimum	78
90-ml point temperature, C	80 maximum	80
Dry-point temperature, C	82 maximum	82
Remarks: Conforms completely		

Appendix B

ANALYTICAL DATA ON PROPRIETARY COATINGS

System Number	Coating	Wt/Gal (lb)	Sp Gr (g/ml)	Viscosity (Krebs Units)	Non-Vol. Solids (%)	Non-Vol. Vehicle (%)	Pigment (%)
1	Urethane Primer	12.7	1.52	1/	61.4	9.9	51.5
	Urethane Topcoat	15.8	1.89	118	75.0	7.0	68.0
2	Epoxy Primer	11.6	1.38	65	66.9	22.3	44.6
	Epoxy Build Coat	12.2	1.46	69	69.6	22.6	47.0
	Epoxy Topcoat	12.5	1.50	69	71.0	23.4	47.6
	Antifouling	13.5	1.62	79	82.7	27.5	55.2
3	Epoxy Primer	11.6	1.38	65	66.9	22.3	44.6
	Polyester	10.5	1.26	97	63.9	35.5	28.4
	Antifouling	13.5	1.62	79	82.7	27.5	55.2
4	Epoxy Primer	14.3	1.72	80	77.0	14.5	62.5
	Coal Tar Epoxy	11.4	1.37	110	82.3	—	31.7 2/
	Epoxy Seal Coat	9.8	1.18	79	87.5	58.1	29.4
	Epoxy Topcoat	11.3	1.36	77	75.5	37.5	38.0
5	Coal Tar Epoxy	15.5	1.86	1/	91.3	—	47.5 2/
	Phenolic Seal Coat	12.2	1.47	92	89.8	43.2	46.6
	Phenolic Topcoat	12.1	1.46	105	83.7	38.0	45.7
6 and 6C	Phenolic Primer	17.5	2.13	1/	96.9	31.3	65.6
	Phenolic Topcoat	13.3	1.60	1/	94.6	48.1	46.5
10	Vinyl Primer	8.2	0.98	54	30.4	11.4	19.0
	Vinyl Body Coat	9.9	1.18	85	50.5	14.0	36.5
	Vinyl Topcoat	7.7	0.92	53	23.3	15.7	7.6
11	Vinyl Phenolic Primer	9.4	0.95	67	37.0	17.2	19.8
	Vinyl Mastic	10.4	1.23	98	57.0	24.1	32.9
12	Inorganic Zinc 3/	10.7	1.28	51 4/	36.1	—	—
	Vinyl Phenolic Primer	9.4	0.95	67	37.0	17.2	19.8
	Vinyl Mastic	10.2	1.23	98	57.0	24.1	32.9

1/ Too viscous for determination

2/ Ash

3/ The values shown are for the vehicle component of the three-package system

4/ Approximate

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U. S. Naval Civil Engineering Laboratory
Technical Report R-246

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INITIATION OF FIELD TESTING, by R. W. Drisko,
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47 p. illus 30 June 63 UNCLASSIFIED

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